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Essentials of Standard Chinese Phonetics for Prosthetic Dentistry

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Abstract

Speech adaptation after oral rehabilitation is based on a complex interaction of articulatory and myofunctional factors. The knowledge of basic phonetic principles may help clinicians identify phonetic problems associated with prosthodontic treatment. The purpose of this article is to illustrate basic phonetic terminology, standard Chinese (Putonghua) phonetics, and the anatomic structures relevant for dentistry. In cooperation with a Chinese linguistic specialist, Chinese articulators were selected and are described and compared with English phonetics. Established test words and sentences aid the identification of mispronounced articulators and their related dental structures. The pronunciation of most consonants and vowels in standard Chinese is similar to English, but some of them, such as the retropalatals (/zh/ [tʂ], /ch/ [thʂ], /sh/ [ʂ]), have notable differences. Palatal consonants (/j/ [tɕ], /q/ [tɕh], /x/ [ɕ]) are unique to the Chinese phonetic system and are not found in English phonetics. The comprehension of the basic anatomic regions involved in Chinese phonetics may help prosthodontists treat patients whose native language is standard Chinese.

Changes in the oral cavity due to the loss of teeth, resorption of the alveolar ridge, or soft- and hard-tissue defects might result in speech deficiencies. Besides restoring an esthetic appearance and masticatory function, prosthetic restorations might compensate for speech deficiencies acquired through the loss of essential anatomic components of the speech system, whereas inappropriate prosthetic restorations can induce speech problems.[1-5] Therefore, basic knowledge of speech physiology for clinical application in prosthetic dentistry seems indispensable.[6-10]

Normal sound production depends on the proper function of five essential elements: (1) the lung and its associated musculature, which supply air; (2) the vocal cords, which give pitch to the tone; (3) the oral, nasal, and pharyngeal cavities and paranasal sinuses, which create resonance; (4) the articulators, consisting of the lips, tongue, soft palate, hard palate, and teeth, which form musculoskeletal valves to obstruct the passage of air by breaking up the tones and producing the individual speech sounds, and (5) innervation of speech muscles, which conveys the motoric impulses to the muscles of speech.[1,2] Phonetics is the study of speech sounds, and articulatory phonetics involves the different articulators during sound production. For a better understanding, some basic phonetic terminology is introduced below.

Phonemes, the smallest units of sound, have a distinctive function. Phonemes contain consonants and vowels, which combine into syllables. The phonation is voiceless or voiced. *Voiceless* sounds are produced by spreading the vocal cords as air from the lungs rushes through, resulting in a hissing noise. *Voiced* sounds are produced by drawing the vocal cords very close together. In this position, the vocal cords are set in vibration by air flowing out from the lungs. The result is a buzzing sound.

Aspiration refers to the puff of air from the mouth, which can be strong (aspirated) or weak (unaspirated). *Stops* are produced by the airflow being fully blocked and then released suddenly to make the noise. *Fricatives* are the result of a partial block of airflow. *Affricative* is a hybrid between stop and fricative. A *lateral sound* is produced by the airflow released along both sides of the tongue (e.g., "L" in "little"). *Liquids* are frictionless consonants, which can be prolonged like vowels.

Consonants are produced by modifying the air steam as it passes through the vocal tract. Consonants are described by two aspects. One is the manner of articulation, which refers to how the sound is produced and the way in which the airflow is modified when it passes through the vocal tract. The other is the place of articulation, the articulators, which are involved to produce a particular sound, i.e., at the lips, the teeth, the alveolar ridge, the palate, or the velum. Sounds produced at the lips are called labials; at the teeth, dentals; at the alveolar ridge, alveolars; at the palate, palatals; and at the velum, velars. In English, sounds produced between teeth are called interdentals. Consonants can be voiced or voiceless.

Vowels are almost always voiced sounds produced by drawing the vocal cords together and vibrating. Vowels are primarily shaped in the vocal tract of the mouth. The tongue's movement divides the space within the mouth in various ways to produce vowels, according to the part of the tongue involved: vowels can be divided into front, central, or back vowels. According to how high the tongue is raised for the production of a certain vowel sound, the vowel can be considered a high, mid, or low vowel. Besides the tongue, the lips are also involved. The lips can be round or spread/unround, dividing into the rounded or unrounded vowel. Vowels include monophthongs, diphthongs, and triphthongs. *Monophthongs* are the sound of a single vowel. *Diphthongs* are combinations of two vowel sounds functioning as a single sound unit. A *triphthong* is a monosyllabic vowel combination involving a quick but smooth movement of the articulator from one vowel quality to another that passes over a third. While monophthongs are said to have one target articulator position, diphthongs have two, and triphthongs three.

The various phonetic realizations of a phoneme are determined by the phonetic environment and are called *allophones*.

The International Phonetic Alphabet (IPA) is a set of international standard alphabet symbols of voice symbols developed by the International Phonetic Association. *Pinyin* is a Chinese system for transliterating standard Chinese phonemes using Romanizations, in which each letter has a fixed phonetic value. There is no difference between spelling and the actual pronunciation as in English.

A literature review revealed that the majority of studies report the influence of denture design on English phonetics.[1-5] No reports on Chinese phonetics in prosthetic dentistry can be found, even though China has the highest population (1.3 billion) in the world.[11] Only literature concerning phonetical problems in Chinese cleft palate patients can be found.[19,20] Edentulism shows an estimated prevalence of up to 70% in seniors over 65 years old worldwide with a low tendency of decline within the past decades.[11,12] Besides this, Chinese is the third most spoken language in the United States and Canada, so prosthodontists have an increasing probability of treating patients whose native language is Chinese.[13-16] Thus, it is of clinical interest to illustrate the basic Chinese phonetic mechanisms in comparison to English and depict the corresponding anatomic parts relevant to prosthodontic treatment. The purpose of this article is to illustrate standard Chinese (Mandarin) phonetics and their relevant anatomic structures and compare it to English phonetics to allow the evaluation or prevention of speech problems during prosthetic treatment.

General clinical procedures

Besides routine examination, including the function and shape of the tongue, lips, and palate, which might ultimately be related to a speech problem, pretreatment speech assessment should be conducted during the initial examination using simple words or phrases (Table 1). The patient should be asked to read these words at a normal speed. A palatogram with a powderous substance (e.g., potato starch) could help identify the contact zone of the tongue in the maxilla during articulation of the consonants involving the palate as described below (Figs 1, 2).

Table 1 Suggested testing sentences with translation into English

Consonants	Test sentences in Chinese	English translation
The labials	Baba peifu mama	Dad admires Mom
The dentals	Saozi hui cunzi	Sister-in-law go back village
The alveolars	Laolao nainai dou teng didi	Both maternal and paternal grandmas dote on the younger brother
The retro-palatals	Shushu ai chi zhurou	Uncle likes to eat pork
The palatals	Jiejie xiang qu Xihu	The elder sister wants to visit Lake Xihu
The velars	Gege haoke	The elder brother is hospitable

Table 2 Standard Chinese consonants with test words

IPA	Pinyin	Test words
[p]	B	baibu (calico), baba (dad)
[pʰ]	P	pipei (match), pingpan (judge)
[m]	M	mimou (plot), maomei (venture)
[f]	F	fafu (gather flesh), feifa (unlawful)
[ts]	Z	zaizuo (be present), zizun (self-esteem)
[tsʰ]	C	caice (guess), cangcu (hurried)
[s]	S	sousuo (search), suosui (pettiness)
[t]	D	dadu (bet), duidai (treat)
[tʰ]	T	tengtong (pain), tanting (snoop)
[n]	N	nainiu (cow), nengnai (ability)
[l]	L	lalong (hook), laolei (tire)
[tʂ]	Zh	zhizhen (pointer), zhuizhu (chase)
[tʰʂ]	Ch	changchu (strong point), chechuang (lathe)
[ʂ]	Sh	shashi (sand), shaoshu (minority)
[ʐ]	R	rongren (tolerance), rouruan (tenderness)
[tɕ]	J	jijiu (first aid), jujue (reject)
[tɕʰ]	Q	qinqie (kindness), qinqi (relative)
[ɕ]	X	xixin (wariness), xiaoxue (elementary school)
[k]	G	gaige (reform), gaogui (dignity)
[kʰ]	K	keku (assiduity), kaikuang (mine)
[X]	h	huihen (regret), honghua (red flower)

Chinese sound selection and analysis

Standard Chinese consonants may be divided into the same articulatory groups as in English, except inter-dentals, which are missing in standard Chinese. According to the anatomic parts involved, standard Chinese consonants can be classified as: (1) labial, (2) dental, (3) alveolar, (4) retro-palatal, (5) palatal, or (6) velar.[15-17] Table 2 shows the difference between the IPA and Pinyin. Compared to English, consonants in standard Chinese

Figure 1 Clinical examination of sounds involving the palate can be performed by using a powderous substance. The moistened palate is dusted with potato starch, and then the patient is asked to pronounce a given sound. The mouth should be opened immediately after sound production to avoid further contact of the tongue with the palate.

Figure 2 Palatogram of [tsh] after pronunciation. The contact zone of the tongue can be seen.

are all voiceless except [l] and [z]. Voicing is a discriminating factor among the English consonants, but not in Chinese. Chinese consonants are discriminated into aspirated or unaspirated. The Chinese consonants occur only in syllable initial positions, never in syllable final position except two nasals, [n] and [η]. In this article, Chinese sounds of dental interest are selected, analyzed, and compared to their English counterparts.

Consonants

The labials: /b/ [p], /p/ [p^h], /m/ [m], /f/ [f]

The labial consonants are made with the use of one or both lips. [p] and [p^h], as in English, are produced with both lips being placed together, and the airstream being stopped as it passes through the vocal tract (Fig 3). [p] is pronounced in a voiceless and unaspirated way, while [p^h] is pronounced with strong exhalation.[17] [m] is a bilabial nasal stop, as in English, which means that when it is produced, the airstream escapes

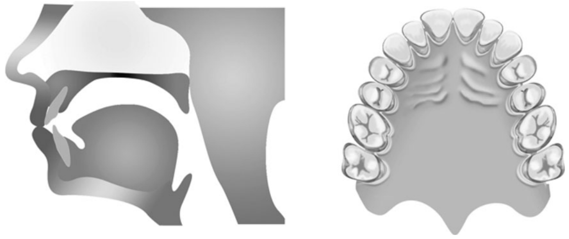

Figure 3 Sagittal diagrams of Chinese labials [p] and [p^h]. The sagittal view shows the position of the tongue within the oral cavity during the formation of the sound. Relevant anatomic areas for dentists are marked in dark gray in the palatal view depicting the area where the tongue touches during the formation of the sound.

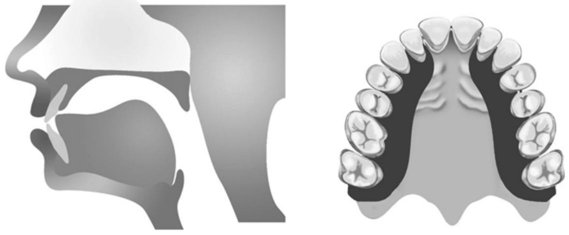

Figure 4 Sagittal and palatal diagrams of Chinese [s]/.

through the nose and not the mouth. The difference is that the vocal cords vibrate when [m] is formed in English, which means that [m] is a voiced sound. [f], as in English, is produced by placing the lower lip against the incisal edges of the maxillary incisors to form a narrowing space through which the air passes with a trace of a hiss.[17,18]

The dentals: /z/ [ts], /c/ [ts^h], /s/ [s]

A Chinese [s] has the same pronunciation as an English [s]. The sound is produced with the tip of the tongue touching the palatal part of the maxillary anterior teeth and both of the lateral parts of the tongue touching the palatal parts of the maxillary teeth. The airstream is sent in a thin, straight line along the groove in the tongue. [s] is a voiceless fricative, which is produced by forcing the airstream through a construction formed by articulators in the vocal tract without vocal cord vibration (Fig 4). [ts] and [ts^h] are completely different from their English counterparts. The tip of the tongue touches the lingual part of the maxillary anterior teeth, the lateral sides of the tongue touching the palatal part of the maxillary anterior teeth (Fig 5). [ts] is voiceless and unaspirated, practically English /ds/, as in "hands." [ts^h] is the aspirated counterpart of [ts], like the /ts/ in the English "hats."[17]

The alveolars: /d/ [t], /t/ [t^h], /n/ [n], /l/ [l]

Chinese alveolar consonants have a similar construction as in English: the tip of the tongue is placed against the alveolar ridge and rugae of the maxillary anterior teeth.[17,18] The sagittal section diagram of these sounds demonstrates that the rugae area of the palate is critical to their formation (Fig. 6). [t] is produced the same way as in English, but with no vibrations in the vocal cords and no exhalation. The sound [t^h] is pronounced

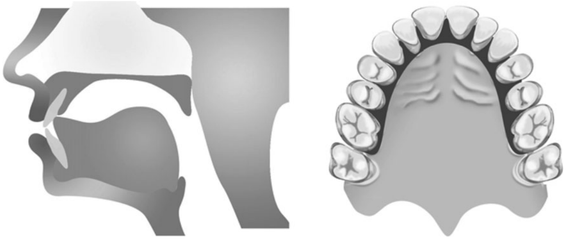

Figure 5 Sagittal and palatal diagrams of Chinese [ts] and [ts^h].

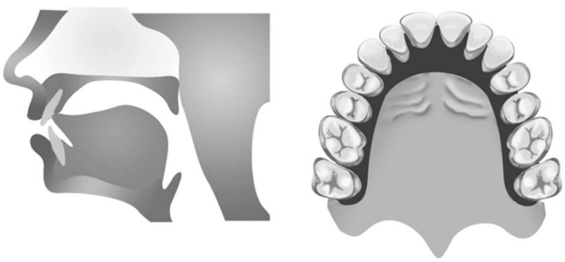

Figure 6 Sagittal and palatal diagrams of Chinese [t] and [t^h].

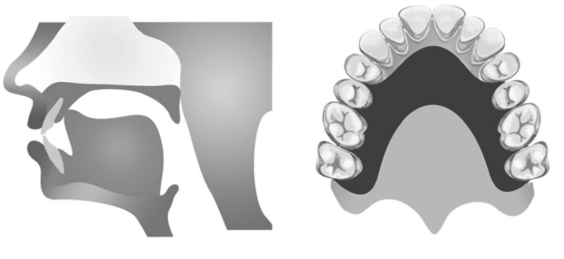

Figure 7 Sagittal and palatal diagrams of Chinese [tʂ] and [t^{h}ʂ].

as in English, but with strong exhalation. Chinese [n] is a nasal stop and pronounced the same way as in English, occurring in both the syllable-initial and syllable-final position. [l] is the same as in English, a voiced lateral liquid produced with the tip of the tongue touching the lingual gingiva of the maxillary anterior teeth with the airflow coming through the bilateral sides of the tongue.

The retro-palatals: /zh/ [tʂ], /ch/ [t^{h}ʂ], /sh/ [ʂ], /r/ [ʐ]

The pronunciation of Chinese retro-palatals [tʂ], [t^{h}ʂ], [ʂ] is different from their English counterparts. They are formed with the tongue curled back so that the tip of the tongue touches the front hard palate to form the dam, and the airflow is aspirated through a thin space between the tip of the tongue and the front hard palate (Figs 7, 8). Chinese [tʂ] and [t^{h}ʂ] are voiceless affricatives. [ʂ] is a voiceless fricative, while [ʐ] is a retro-palatal liquid, the only voiced fricative in Chinese. It is pronounced with the tip of the tongue curled upward and backward and is practically the same as the English "r" in the word "read."[17]

The palatals: /j/ [tɕ], /q/ [tɕ^h], /x/ [ɕ]

The Chinese palatal consonants cannot be found in English sounds. They are formed with the middle part of the tongue

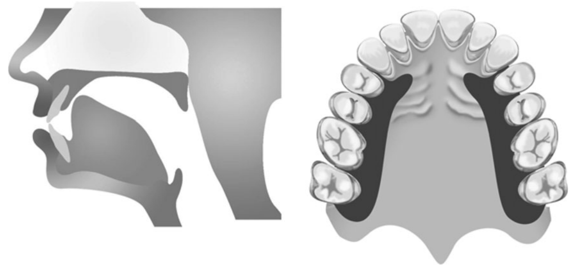

Figure 8 Sagittal and palatal diagrams of Chinese [ʂ].

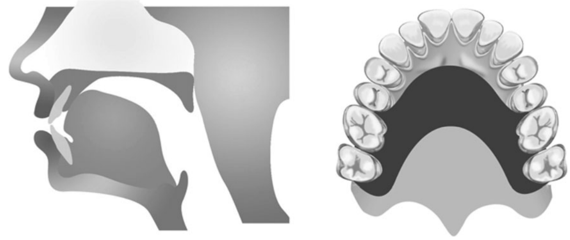

Figure 9 Sagittal and palatal diagrams of Chinese [tɕ], [tɕ^h], and [ɕ].

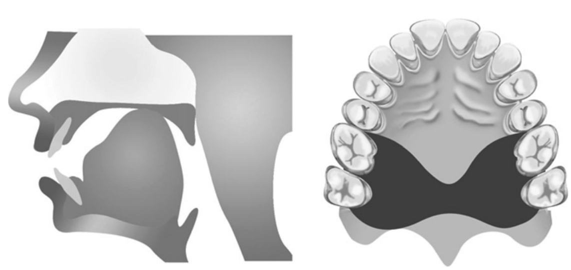

Figure 10 Sagittal and palatal diagrams of Chinese [k] and [k^h].

touching the hard palate, simultaneously with both lateral parts of the tongue touching the palatal part of the maxillary posterior teeth to form the dam, the airflow released through a thin space between the anterior part of the tongue and the hard palate (Fig 9). [tɕ] and [tɕ^h] are voiceless affricatives, while [ɕ] is voiceless fricative.

The velars: /g/ [k], /k/ [k^h], /h/ [x], /ng/ [*η*]

In this group of sounds, [k] and [k^h] are produced the same way as their English counterparts, but [k] lacks vibration in the vocal cords, and [k^h] requires strong exhalation. [k] and [k^h] sounds are formed by pressing the back part of the tongue against the soft palate, quickly lowering it, and with the sudden release of air, slight explosive sounds are made (Fig 10). [x] is a voiceless velar fricative, while [*η*] is velar nasal and syllable-final.

Vowels

A vowel is pronounced using one uninterrupted breath of air without closing the mouth or throat. To produce vowels, the soft palate contracts and seals the pharynx with the aid of the pharyngeal musculature, which restricts the passing of air into the nasal cavity.[17,18] There are five simple vowels in Chinese;

among them, four are the same as English. [a] and [i] are the same as the English [a] and [i]. The Chinese schwa [γ] is the same as the English [γ]. Though it is phonetically [γ], the Pinyin for it is "e." [u] is slightly different from the English vowel [u], as it is raised more in the back.[17] [y], a high front rounded vowel, is unique to Chinese and pronounced with the tongue like the high front un-rounded [i], but with the lips rounded as for the high rounded [u]. In English there are nine tongue positions for six vowels, but only five for the five vowels in Chinese. This leaves more room for allophones due to greater space between the Chinese vowels. Besides simple vowels as in English, Chinese also has diphthongs and triphthongs, which have one main vowel and are pronounced with a continuous airsteam.[17]

Discussion

Prosthodontic treatment involves clinical procedures that affect speech articulation directly or indirectly. Speech is a dynamic process, in which different anatomic structures are involved and can be divided into static and dynamic structures.[3] The static structures, such as the teeth, the alveolar ridge, and the palate, are important in establishing the route the air takes, as well as providing some of the obstructions against which the air strikes to produce a sound. The dynamic structures include the tongue, lips, and velum. The tongue is the most versatile of the three, which limits the space in the mouth differently for each sound. Rebuilding the static structures in their natural contours with prosthetics with an optimal environment for the dynamic structures ensures acceptable speech. Words containing the dentals, the retro-palatals, and the palatals can be used to test articulation in Chinese-speaking patients.

The interarch distance and the 3D position of the maxillary anterior teeth may influence the labials. Clinically, Chinese [f] is used to check the position of the maxillary anterior teeth. [f] is correctly pronounced when the maxillary anterior teeth are in the right position for the incisal edges to make a definite seal against the lower lip at or near the wet/dry line. Renji et al reported that Chinese patients with cleft lip and palate could not find the right position to produce [p], [p^h], and [f], while [m] was the least influenced.[19]

Common factors influencing the dentals include: thickness of the denture base in the anterior part of the palate, the position of the anterior teeth, palatal eminences bilaterally in the maxillary bicuspid regions, vertical dimension, and interincisal space. Clinically, words containing the dentals such as /sishisi/ [sɪʂɪsɪ] ("forty four") in Chinese can be used to help determine vertical dimension. [ts^h] is one of the most frequently distorted sounds in Chinese patients with functional speech problems.[19]

An abnormal protrusion of the incisors, a marked overbite or overjet, and abnormal rugae contour may impair correct pronunciation of the alveolar consonants.[20,21] If the anterior teeth were set in malposition, this might interfere with the proper positioning of the tongue, causing a speech deficiency of the alveolars. Meanwhile, if the tongue cannot find some rugae against which to base itself in making the dam for impounding air, [t] and [t^h] may also be poorly pronounced. Renji et al reported that in more than 40% of cleft palate patients, the tongue could not find the rugae when [t] and [t^h] were pronounced.[19] In standard Chinese, if the back part of the tongue cannot form a dam with the soft palate, the velars [k] and [k^h] can be distorted. This is also called a velum sound abnormality.[19] The distortion of [l] is usually found in patients with functional speech problems. This may be due to poor flexibility of the tongue and wrong pronunciation habits.[20,22,23]

Factors affecting the dentals may also influence the retro-palatals and palatals. If the back of the tongue cannot form a dam with the front part of the palate, the retro-palatals may be distorted.[22] [tʂ] and [t^{h}ʂ] are the most frequently distorted sounds in more than 60% of cleft palate patients, while [ʂ] and [ʐ] are not distorted as often as [tʂ] and [t^{h}ʂ].[20,22,24]

More than 50% of patients could not produce [tɕ] and [tɕ^h] correctly after cleft palate surgery.[20] If the tongue blade contacts the hard palate to form the dam instead of the tongue tip forming the dam at the palatal part of the maxillary anterior teeth, the palatals may be as distorted as the dentals. Similarly, if the tongue tip cannot form a dam at the anterior part of the hard palate, the retro-palatals may distorted like the palatals.[22]

To produce the sound [k] and [k^h], a complete velopharyngeal closure is needed to build up the pressure in the mouth for aspiration. Any factors influencing the complete closure may cause this kind of speech defect, which is usually met in cleft palate patients.[20,22,24] [x] is a voiceless velar fricative in Chinese phonetics, but it is less affected compared with other Chinese fricatives in patients with functional speech problems.[20,22] If the maxillary denture is overextended and irritates the velum, or the denture does not make firm contact with the tissue at the posterior palatal seal, it may also influence the enunciation of the velars.

Vowels are pronounced with continuous airflow and usually follow the consonants, so if the denture allows for the correct pronunciation of consonants, the vowels present little or no trouble.[24,25]

Conclusion

Analysis of phonetic sound production in prosthodontic practice should be based on some understanding of the nature of the speech sounds, how they are produced, and the anatomic and physiologic structures involved. The pronunciation of most standard Chinese phonemes is similar to the pronunciation of their English counterparts, but some of the dentals, retro-palatals, and palatals have notable differences.

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